The dipole flow in Cu+Au and Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR detectors

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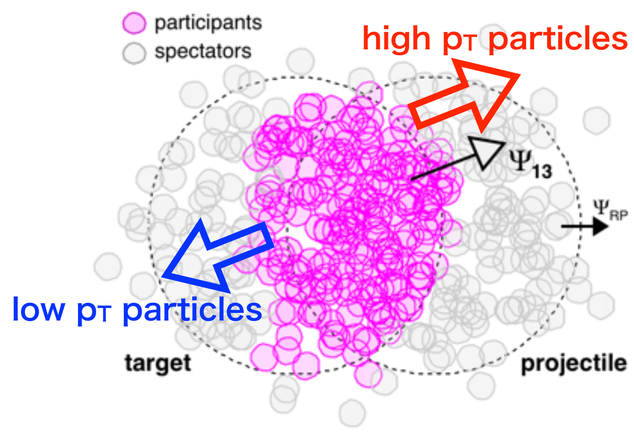
What is dipole flow?

- Initial density asymmetry due to the density fluctuations
- Direction of the largest density gradient Ψ_{13} can be defined as [1]:

$$\Psi_{1,3} = \tan^{-1}\left(\frac{\langle r^3 \sin(\phi)\rangle}{\langle r^3 \cos(\phi)\rangle}\right) + \pi$$

Particles with higher p_T are emitted to the direction of Ψ_{13}, while low p_T particles go to the opposite direction.



<u>characteristic features of the dipole flow</u>

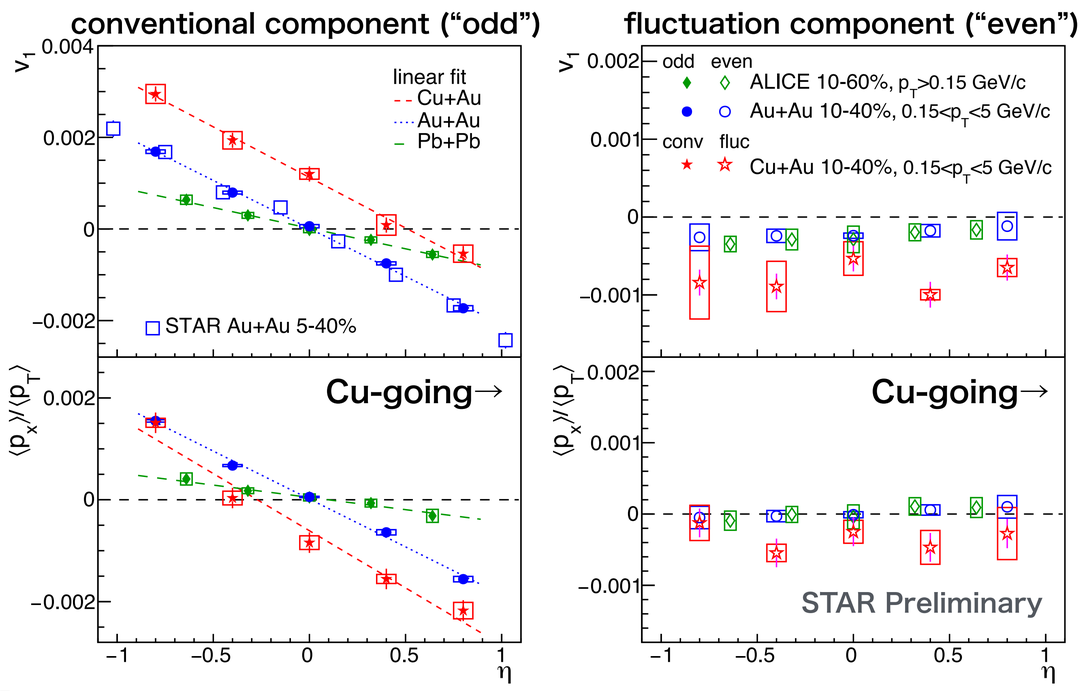
- sign-change in its p_T dependence
- mean transverse momentum of all particles is zero ($\langle p_x \rangle = 0$)
- weak pseudorapidity (η) dependence
  → even component of directed flow (v_1^{even})

Unique probe to the initial density fluctuation and the hydrodynamical response of the fluctuation

Experimental Results

v_1^{even} can be measured by making use of a correlation between Ψ_{13} and **spectator planes (Ψ_{Spec})** [2,3]

$$v_1 = v_1^{\mathrm{odd}}(\eta) + v_1^{\mathrm{even}}$$
$$v_1^{\mathrm{odd(conv)}} = (v_1\{\Psi_{\mathrm{Spec}}^P\} - v_1\{\Psi_{\mathrm{Spec}}^t\})/2$$
$$v_1^{\mathrm{even(fluc)}} = (v_1\{\Psi_{\mathrm{Spec}}^P\} + v_1\{\Psi_{\mathrm{Spec}}^t\})/2$$



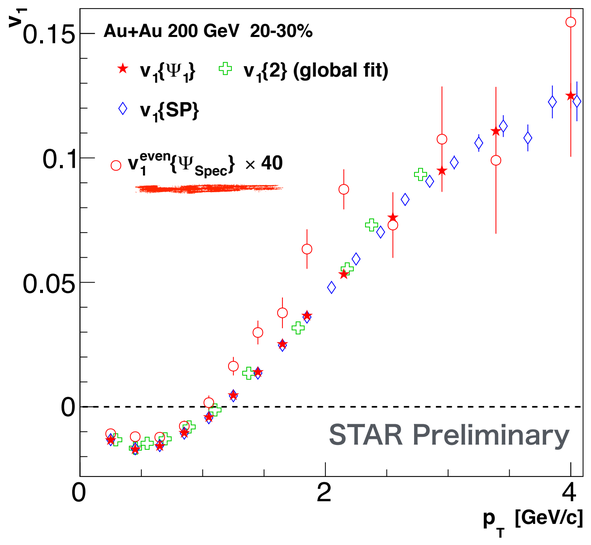
Even component

- ★ consistent between Au+Au and Pb+Pb, indicating a similar magnitude of the initial density asymmetry
- ★ magnitude for Cu+Au is larger but note that $\langle p_x \rangle \neq 0$

Odd component

- ★ similar slope of v_1 between Au+Au and Cu+Au but steeper slope of $\langle p_x \rangle$ in Cu+Au, probably to balance the momentum between the forward and backward directions ($dN^{Au}/d\eta > dN^{Cu}/d\eta$)

v_1^{even} can be also measured with **two-particle correlation** ($v_1\{2\}$) and **event plane/scalar product methods** ($v_1\{\Psi_1\}$ and $v_1\{SP\}$) by taking care of the effect of the momentum conservation [4,5].

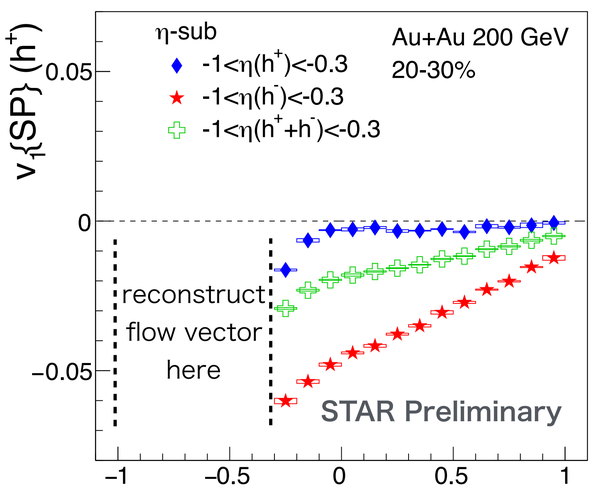


$$Q_{n,x} = \sum w_i \cos(n\phi_i)$$
$$Q_{n,y} = \sum w_i \sin(n\phi_i)$$
$$\Psi_n = \tan^{-1}(Q_{n,x}/Q_{n,y})/n$$
$$w_i = p_T - \langle p_T^2 \rangle / \langle p_T \rangle$$

Factor of ~40 difference in magnitude between $v_1^{even}\{\Psi_{Spec}\}$ and other methods as observed at the LHC. How can we understand this difference?

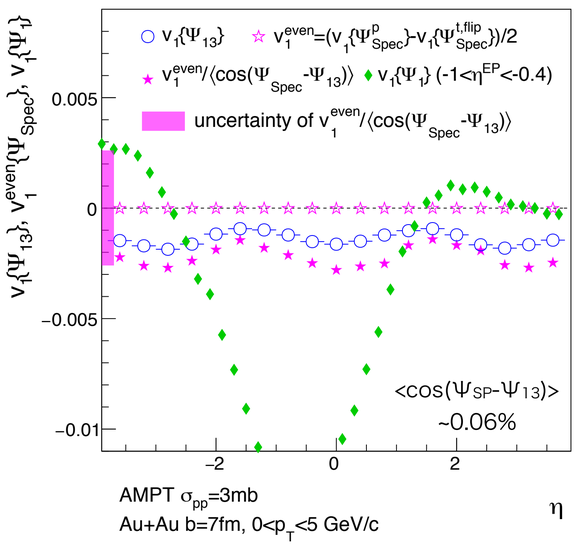
★ Strong η ($\Delta\eta$) dependence
★ Strong charge dependence
(when using charge-separate η-sub)

The dipole flow is expected to be less dependent of η and charge. Results indicate that $v_1\{SP\}$ (or $v_1\{\Psi_1\}$) is dominated by non-flow.



Stronger η dependence in the unlike-sign combination.
- due to away-side jet?

Implications from AMPT model



$v_1\{\Psi_{13}\}$ is a "dipole flow" and a baseline in this study.
(note: resolution effect of Ψ_{13} could be in $v_1\{\Psi_{13}\}$)

★ $v_1^{even}\{\Psi_{Spec}\}$ is much smaller than $v_1\{\Psi_{13}\}$ but **$v_1^{even}\{\Psi_{Spec}\}$ /$\langle\cos(\Psi_{Spec}-\Psi_{13})\rangle$ is very close to $v_1\{\Psi_{13}\}$** and has a similar η dependence.

★ **$v_1\{\Psi_1\}$ doesn't agree with $v_1\{\Psi_{13}\}$ even at large η ($\Delta\eta$ from the subevent)**, suggesting a difficulty to measure the dipole flow with the current methods of $v_1\{\Psi_1\}$ and $v_1\{SP\}$.

Summary

★ Observed similar magnitude of $v_1^{even}\{\Psi_{Spec}\}$ in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV and Pb+Pb at $\sqrt{s_{NN}}$ = 2.76 TeV.
★ The dipole flow can be measured using Ψ_{Spec} but is smeared by the correlation between Ψ_{Spec} and Ψ_{13}, which is unknown in general.

Acknowledgement

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References

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